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TRANSLATION

ABRASIVE PROPERTIES OF MICROCONTAMINATION AND OXIDATION PRODUCTS OF JET FUELS

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ABRASIVE PROPERTIES OF MICROCONTAMINATION AND OXIDATION PRODUCTS OF JET FUELS

V. A. Piskunov and V. N. Zrelov

In the course of the established period of service of the air-breathing jet engine (AJE), there is consumed a great amount of fuel calculated for the separate types of boosted [forced] engine by tens of thousands of tons [1]. As a result of the strained operation of the fuel apparatus of the engine up to 50% of the breakdowns in the work of the AJE are to be attributed to the fuel-supplying systems.

Very great significance for the assuring of dependable operation and increasing the period of service of the fuel apparatus of the AJE is to be attached to the quality of the fuel and particularly to its purity.

In the process of transportation, storing, and dispensing impurities get into the fuel, which represent the products of corrosion of the storage equipment and mineral admixtures penetrating from the surrounding air [2, 3]. The purity of the fuel goes down even in the fuel system of the airplane through the dust from the air, the products of corrosion and the wear of parts, and also settlings from thermo-oxidational origin [4, 5].

Up to the present time, it has not been established what degree of contamination of the fuel is dangerous for the fuel equipment of a jet engine. However, the Orend concern [6] indicates that the presence of foreign particles in the amount of 15 mg/l of fuel can lead to the breakdown of plunger pumps after 100 hours of operation. An amount of contamination not exceeding 1 mg/l of fuel does not cause a lowering of the dependability of the working of these pumps. At the same time from experience in operation, it is known that the dependable working of the engines in the course of its whole service life is assured by fuel containing foreign admixtures up to 2 to 3 mg/l.

A number of researchers consider that in order to judge of the effect of contaminants on the working of an engine, it is important to know only their overall amount of fuel. Others maintain that for the operation of the fuel, particles above a definite size are dangerous and they set for this figure 10 μ. In the opinion of some authors [7], the size is not so important as the content in the fuel of solid inorganic admixtures.

In this situation, they consider that the basic source of wear

Table 1

Amount and kind of microcontaminants in fuels before fuel-controlling apparatus of an AJE

1 Микрозагрязнения	2 Топлива	
	Т-1	ТС-1
3 Количество, г/т	1,52—6,4	0,8—0,9
4 Влажность, %	9,5—19,4	17,8—28,5
5 Зольность, %	56,9—61,1	54,5—69,6
6 Состав, тыс. частиц на 1 л:		
1 μ	2218—6250	1890—3420
3 μ	1181—2320	820—1640
5 μ	429—785	500—765
10 μ	107—203	179—321
15 μ	25—72	143—163
20 μ	18—20	36—107
30 μ	9—10	—
7 Элементарный состав, %:		
C	20,4—20,9	17,94—23,19
H	8,60—10,8	5,1—6,08
S	0,29—0,69	0,07—0,22
N	1,47—2,47	0,25—0,36
O	31,45—36,91	30,86—43,02
Fe	10,9—15,4	2,85—19,0
Si	3,92—13,2	6,8—11,3
Ca	2,19—3,97	2,85—3,82
Mg	2,32—5,7	2,6—3,44
Na	1,71—4,6	0,13—0,55
Al	2,80—7,2	0,51—3,8
Cu	0,34—1,03	0,16—0,5

Note: Ti, Cr, and Mn are present in small quantities; Ba, Sb, Sn, Co, Cd, Ag, P, Mo, V, Bi, and Be are absent.

KEY: 1 - microcontaminants; 2 - fuel; 3 - amount, g/t; 4 - moisture, %; 5 - ash, %; 6 - make-up, thous. particles per litre; 7 - element make-up, %.

of parts is friction. However, as researches have shown on reactive engines, it is not only friction but also abrasive contamination (erosion) of the parts of the fuel apparatus in the form of cuts and scratches of the parts by material transported by the fuel along the small tubes and jets with great speed (3.0 to 5.0 m/sec).

Thus on engines that have been operated for the guaranteed service period one observes erosion of the atomizers of the fuel sprayers

and jets of the system of control and the openings of the throttle devices of the pumps.

The characteristics of the microcontaminants which enter with the fuels in the fuel-regulating apparatus of an AJE are presented in Table 1.

From the data presented, it is seen that in the fuel-controlling apparatus of jet engines, fuel enters which contains considerable amounts of microcontaminants. In the fuel TS-1, such microcontaminants can be present in the amount 0.8 to 0.9 g/t with the dimension of the particles up tp 20 μ, and in the fuel T-1, 1.52 to 6.4 g/t with the dimension of the particles up to 30 μ. The overall amount of microcontaminants (with particle dimensions of from 1 to 20 - 30 μ) in 1 liter of fuel amounts to 3500 - 6500 thousand particles in the fuel TS-1 and 4000 - 10,000 thousand particles in the fuel T-1.

The study of the make-up of the microcontaminant of fuel has shown that 60 to 70% of the microcontaminants represent solid products (oxides of iron, silicon, calcium, magnesium, aluminum, sodium, and copper) which belong to the compounds with noticeably pronounced abrasive properties.

In the fuel systems of the supersonic airplanes, the fuel undergoes an intense heating up to the temperature of 100 to 150°C. Under these conditions in the fuels there is formed a great quantity of hard insoluble residues from thermo-oxidation sources [8]. As is seen from Table 2 in the fuel TS-1 at the temperature at 150°C, there are formed residues of 84.7 g/t; in the fuel T-1, 144.9 g/t; and in the fuel T-5,

Table 2

Amount and kind of residues formed in jet fuels of heating up to 150°C

1 Характеристика осадков	2 Топлива		
	ТС-1	Т-1	Т-5
Количество, г/т 3	84,7	144,9	44,9
Зольность, % 4	24,4	12,3	5,0
Элементарный состав 5, %:			
C	50,0	49,0	62,7
H	4,9	4,6	5,3
S	6,0	5,0	5,9
N	1,7	1,6	3,5
O (по разности) 6	22,2	32,1	20,2
Fe	0,7	0,4	0,12
Si	0,97	1,2	1,3
Cu	11,2	3,41	0,05
Ca	0,37	0,5	0,17
Na	0,04	0,4	0,13
Al	0,7	0,5	0,1

KEY: 1 - characteristics of residues; 2 - fuel; 3 - amount, g/t; 4 - ash, %; 5 - element make-up, %; 6 - (by difference).

44.9 g/t. These residues contain particles of from 1 to 1000 μ.

The residues contain a large amount of solid large-molecule resinous substances and considerable amount of compounds of copper.

For explaining the character of the abrasive wear of the parts of the fuel apparatus brought about by microcontaminants and residues, we conducted the following experiments.

On fuel pumps of an AJE under stand conditions, there was tested the fuel TS-1 containing up to 30 mg/l of microcontaminants on heating the fuel up to 100 - 150°C.

The procedure of the research consisted in determining the time of the transition of the fuel pump from the minimum production to the maximum. This time with other conditions being equal by the output

Table 3

Change in the hydraulic characteristic of an airplane plunger pump after working on different fuels at 150°C

Показатели	Изменение времени перехода насоса с минимальной производительности на максимальную (сек) на топливах		
	ТС-1, содержащем осадков 39 г/т	Т-5, содержащем осадков 26 г/т	ТС-1 с корундовым порошком (1–7 мк) в количестве 20 г/т
До испытаний:			
давление топлива на выходе из насоса, кГ/см²:			
10	6,2	5,0	3,1
50	7,5	7,2	5,5
После 5 ч испытаний:			
давление топлива на выходе из насоса, кГ/см²:			
10	5,8	4,0	2,1
50	7,0	6,2	4,9

KEY: 1 - indices; 2 - change in the time of transition of the pump from the minimum to the maximum (sec) for the fuels; 3 - TS-1, containing residues 39 g/t; 4 - T-5, containing residues 26 g/t; 5 - TS-1 with corundum powder (1 - 7 μ) in Amt. 20 g/t; 6 - before the tests; 7 - pressure of fuel at output from pump, kg-wt/cm^2; 8 - after 5 hours of testing; 9 - pressure of fuel at output from pump, kg-wt/cm^2.

capacity of a special jet nozzle.

The hydraulic characteristics of the pump were checked with a new jet nozzle and one which had worked for 5 hours (600 change-overs) on fuel with microcontaminants consisting of products of oxidation origin.

In Table 3, there one sees that the time of the transition of the pump from one productiveness to the other gets less as a result of the abrasive erosion of a section of the regulating jet nozzle.

Such a phenomenon in the operation of aviation AJE is completely unallowable, since it can lead to an entirely too great a reduction of the time of pickup of the engine and to the burnout of the parts.

From Table 3 also it is seen that the abrasive wear of the jet nozzle with fuel TS-1 with corundum powder proves to be practically the same as with the fuels with natural microcontaminants.

The greatest abrasive wear of the parts of the hydraulic channels of the fuel-regulating parts of aviation apparatus will be observed on the engines with entended service life and supersonic AJE, where, besides the mineral microcontaminants, in the fuel there appear insoluble residues of thermo-oxidation origin.

In this way the microcontaminants in the fuel bring about not only a clogging of the pores of the filters, but also prove to be a source of abrasive wear of the parts of the flow section of the fuel-regulating apparatuses of the engines.

Conclusions

1. Microcontaminants and residues from thermooxidation origin in fuel are the cause of abrasive wear of the hydraulic channels and jet nozzles of the fuel-regulating apparatus of jet engines.

2. The extent of the abrasive wear of the fuel-regulating apparatus of the engines depends on the amount and make-up of the microcon-

taminants and residues in the fuel determinable by the conditions of the transportation, storage, and application of the fuels and their thermal stability.

3. For lowering the abrasive action of the microcontaminants and residues, it is necessary to increase the fineness of the filtration and improve the thermal stability of the fuels (additives, etc.).

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